CAMBRIDGE

Cambridge University Press
978-0-521-19569-0 - Mechanical Behavior of Materials: Second Edition
William F. Hosford
Table of Contents
More information

Contents

Preface *page* xiii

1 **Stress and Strain** 1
Introduction 1
Stress 2
Sign Convention 3
Transformation of Axes 4
Principal Stresses 6
Mohr's Stress Circles 6
Strains 9
Small Strains 11
Transformation of Axes 12
Mohr's Strain Circles 13
Force and Moment Balances 14
Boundary Conditions 16
Note 17
Problems 17

2 **Elasticity** 20
Introduction 20
Isotropic Elasticity 20
Variation of Young's Modulus 22
Isotropic Thermal Expansion 24
Elastic Anisotropy 25
Orientation Dependence of Elastic Response 27
Orientation Dependence in Cubic Crystals 28
Orientation Dependence in Noncubic Crystals 30
Orientation Dependence in Materials Other Than Single Crystals 31
Anisotropic Thermal Expansion 31
References 32
Notes 32
Problems 33

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-19569-0 - Mechanical Behavior of Materials: Second Edition
William F. Hosford
Table of Contents
More information

3 **Mechanical Testing** 36
Introduction 36
Tensile Specimens 36
Stress–Strain Curves 37
Ductility 40
True Stress and Strain 41
The Bridgman Correction 43
Temperature Rise 43
Sheet Anisotropy 44
Measurement of Force and Strain 45
Axial Alignment 46
Special Problems 47
Compression Test 47
Plane–Strain Compression 50
Plane–Strain Tension 51
Biaxial Tension (Hydraulic Bulge Test) 51
Torsion Test 53
Bend Tests 54
Hardness Tests 56
Mutual Indentation Hardness 59
References 60
Notes 60
Problems 61

4 **Strain Hardening of Metals** 65
Introduction 65
Mathematical Approximations 65
Power Law Approximation 67
Necking 68
Work Per Volume 70
Localization of Strain at Defects 70
Notes 71
Problems 72

5 **Plasticity Theory** 74
Introduction 74
Yield Criteria 74
Tresca (maximum shear stress criterion) 75
Von Mises Criterion 76
Flow Rules 78
Principle of Normality 79
Effective Stress and Effective Strain 80
Other Isotropic Yield Criteria 82
Anisotropic Plasticity 84
Effect of Strain Hardening on the Yield Locus 86
References 87

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-19569-0 - Mechanical Behavior of Materials: Second Edition
William F. Hosford
Table of Contents
More information

Notes 87
Problems 88

6 **Strain Rate and Temperature Dependence of Flow Stress** 92
Introduction 92
Strain Rate Dependence of Flow Stress 92
Superplasticity 95
Combined Strain and Strain Rate Effects 99
Strain Rate Sensitivity of bcc Metals 100
Temperature Dependence 103
Combined Temperature and Strain Rate Effects 103
Hot Working 108
References 109
Notes 109
Problems 110

7 **Slip and Crystallographic Textures** 113
Introduction 113
Slip Systems 113
Schmid's Law 113
Strains Produced by Slip 116
Strain Hardening of fcc Single Crystals 117
Tensile Deformation of fcc Crystals 118
Slip in bcc Crystals 120
Slip in hcp Crystals 121
Lattice Rotation in Tension 121
Lattice Rotation in Compression 123
Texture Formation in Polycrystals 124
Approximate Calculations of R Values 125
Deformation of Polycrystals 126
Texture Strengthening 127
Effects of Texture on Microstructure 128
References 132
Notes 132
Problems 133

8 **Dislocation Geometry and Energy** 137
Introduction 137
Theoretical Strength of Crystals 137
The Nature of Dislocations 139
Burgers Vectors 141
Energy of a Screw Dislocation 142
Reactions between Parallel Dislocations and Frank's Rule 144
Stress Fields around Dislocations 144
Forces on Dislocations 146
Partial Dislocations in fcc Crystals 147
Stacking Faults 149

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-19569-0 - Mechanical Behavior of Materials: Second Edition
William F. Hosford
Table of Contents
More information

References 152
Notes 152
Problems 153

9 **Dislocation Mechanics** 155
Introduction 155
Frank-Read Sources 155
Dislocation Pile-Ups 158
Cross-Slip 158
Dislocation Intersections 159
Climb 163
References 163
Note 163
Problems 164

10 **Mechanical Twinning and Martenitic Shear** 166
Introduction 166
Formal Notation 167
Twinning Shear 167
Twinning in fcc Metals 169
Twinning in bcc Metals 169
Twinning in hcp Metals 171
Shapes of Twins 173
Mechanism of Twinning 175
Martensite Transformation 178
Shape Memory and Superelasticity 178
References 181
Note 181
Problems 181

11 **Hardening Mechanisms in Metals** 184
Introduction 184
Crystal Structure 184
Grain Size 184
Strain Hardening 186
Solid Solution Strengthening 187
Dispersion Strengthening 188
Yield Points and Strain Aging 191
Combined Effects 192
References 195
Notes 195
Problems 196

12 **Discontinuous and Inhomogeneous Deformation** 199
Stick-Slip Phenomena 199
Dynamic Strain Aging 200
Other Causes of Serrated Stress–Strain Curves 205

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-19569-0 - Mechanical Behavior of Materials: Second Edition
William F. Hosford
Table of Contents
More information

Strain Localization 205
Reference 206
Notes 206
Problems 206

13 **Ductility and Fracture** 208
Introduction 208
Ductile Fracture 210
Brittle Fracture 216
Impact Energy 218
References 221
Notes 221
Problems 223

14 **Fracture Mechanics** 225
Introduction 225
Theoretical Fracture Strength 225
Stress Concentration 227
Griffith Theory 227
Orowan Theory 229
Fracture Modes 229
Irwin's Fracture Analysis 229
Plastic Zone Size 231
Thin Sheets 233
Temperature and Loading Rate 234
Metallurgical Variables 235
Fracture Mechanics in Design 235
Compact Tensile Specimens 236
Strain–Energy Release 237
The J Integral 238
References 240
Notes 240
Problems 241
Appendix. Size and Shape of the Plastic Zone at the Crack Tip 243

15 **Viscoelasticity** 244
Introduction 244
Rheological Models 244
Series Combination of Spring and Dashpot 245
Parallel Combination of Spring and Dashpot 246
Combined Series Parallel Model 246
More Complex Models 248
Damping 248
Natural Decay 249
Elastic Modulus – Relaxed versus Unrelaxed 250
Thermoelastic Effect 251
Snoek Effect in bcc Metals 253

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-19569-0 - Mechanical Behavior of Materials: Second Edition
William F. Hosford
Table of Contents
More information

Other Damping Mechanisms 254
References 255
Notes 255
Problems 256

16 **Creep and Stress Rupture** 259
Introduction 259
Creep Mechanisms 259
Temperature Dependence of Creep 263
Deformation Mechanism Maps 264
Cavitation 265
Rupture versus Creep 266
Extrapolation Schemes 266
Alloys for High-Temperature Use 269
References 271
Notes 271
Problems 272

17 **Fatigue** 275
Introduction 275
Surface Observations 275
Nomenclature 276
S-N Curves 278
Effect of Mean Stress 279
The Palmgren-Miner Rule 281
Stress Concentration 282
Surfaces 284
Design Estimates 285
Metallurgical Variables 286
Strains to Failure 286
Crack Propagation 289
Cyclic Stress–Strain Behavior 292
Temperature and Cycling Rate Effects 292
Fatigue of Polymers 295
Fatigue Testing 297
Design Considerations 297
Summary 298
References 298
Notes 298
Problems 299

18 **Residual Stresses** 302
Introduction 302
Small-Scale Stresses 302
Bauschinger Effect 305
Nonuniform Cooling 306
Nonuniform Material 307

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-19569-0 - Mechanical Behavior of Materials: Second Edition
William F. Hosford
Table of Contents
More information

Stresses from Welding 307
Stresses from Mechanical Working 308
Consequences of Residual Stresses 310
Measurement of Residual Stresses 311
Relief of Residual Stresses 313
References 314
Notes 314
Problems 315

19 **Ceramics and Glasses** 318
Introduction 318
Elastic Properties 318
Slip Systems 319
Hardness 319
Weibull Analysis 321
Testing 322
Porosity 323
High-Temperature Behavior 324
Fracture Toughness 324
Toughening of Ceramics 326
Fatigue 329
Silicate Glasses 329
Strength of Glasses 332
Thermally Induced Stresses 333
Delayed Fracture 334
Glassy Metals 334
References 336
Notes 336
Problems 337

20 **Polymers** 339
Introduction 339
Elastic Behavior 339
Rubber Elasticity 344
Damping 345
Yielding 347
Effect of Strain Rate 348
Effect of Pressure 350
Crazing 354
Yielding of Fibers in Compression 356
Fracture 356
Deformation Mechanism Maps 357
Shape-Memory Effect 357
References 360
Notes 360
Problems 361

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-19569-0 - Mechanical Behavior of Materials: Second Edition
William F. Hosford
Table of Contents
More information

21 **Composites** 363
Introduction 363
Fiber-Reinforced Composites 363
Elastic Properties of Fiber-Reinforced Composites 363
Strength of Fiber-Reinforced Composites 367
Volume Fraction of Fibers 368
Orientation Dependence of Strength 369
Fiber Length 369
Failure with Discontinuous Fibers 372
Failure under Compression 373
Typical Properties 374
Particulate Composites 375
Brick Wall Model 376
Lamellar Composites 378
Morphology of Foams 379
Mechanical Properties of Foams 379
Metal Foams 379
Flexible Foams – Open Cell 381
Flexible Foams – Closed Cell 381
References 381
Notes 382
Problems 382

22 **Mechanical Working** 385
Introduction 385
Bulk-Forming Energy Balance 385
Deformation Zone Geometry 389
Friction in Bulk Forming 392
Formability 393
Deep Drawing 394
Stamping 396
References 401
Notes 401
Problems 402

APPENDIX I: Miller Indices 407

APPENDIX II: Stereographic Representation of Orientations 412

Index 415

© in this web service Cambridge University Press www.cambridge.org